TRENDS IN SELECTED WATER-QUALITY CHARACTERISTICS, FLATHEAD RIVER AT FLATHEAD, BRITISH COLUMBIA, AND AT COLUMBIA FALLS, MONTANA, WATER YEARS 1975-86

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CONVERSION FACTORS

The following factors can be used to convert inch-pound units to metric (International System) units.

Multiply inch-pound unit	By	To obtain metric unit
cubic foot per second	0.028317	cubic meter per second
mile	1.609	kilometer

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ (°C) + 32$$

TRENDS IN SELECTED WATER-QUALITY CHARACTERISTICS, FLATHEAD RIVER AT FLATHEAD, BRITISH COLUMBIA, AND AT COLUMBIA FALLS, MONTANA, WATER YEARS 1975-86

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ABSTRACT

Data for selected water-quality characteristics were analyzed for trends at two sampling stations--Flathead River at Flathead, British Columbia (Flathead station) and Flathead River at Columbia Falls, Montana (Columbia Falls station). The purpose of this report is to describe the methods of analysis and the trends detected in the water quality of streamflow. The data analyzed were collected during water years 1975-86 at the Flathead station and water years 1979-86 at the Columbia Falls station.

The seasonal Kendall test was applied to flow-adjusted data for some characteristics and to unadjusted data for the remaining characteristics. Slope estimates were made for the adjusted data of characteristics that had significant trends. At the Flathead station, increasing trends existed in the adjusted concentrations of dissolved solids (0.3 percent per year), calcium (0.3 percent per year), magnesium (0.4 percent per year), sodium (3.7 percent per year), total organic nitrogen (7.5 percent per year), and total phosphorus (2.6 percent per year). Increasing trends also existed in the concentrations of dissolved nitrite plus nitrate nitrogen, and ammonia nitrogen (total and dissolved). Decreasing trends were present in the unadjusted concentrations of dissolved iron and of total nitrite plus nitrate nitrogen. No trends were detected in the data for the remaining 10 characteristics that were analyzed. At the Columbia Falls station, increasing trends occurred in the concentrations of calcium (1.1 percent per year) and magnesium (0.6 percent per year). Decreasing trends occurred in the adjusted concentrations of sulfate (4.5 percent per year) and the unadjusted concentrations of dissolved phosphorus. No trends were detected in the data for the remaining 10 characteristics that were analyzed.

The data collected at the Flathead station during water years 1979-86 also were reanalyzed and compared to data from the Columbia Falls station for the same period. At the Flathead station, increasing trends occurred in the adjusted concentrations of magnesium and dissolved nitrite plus nitrate nitrogen. A decreasing trend was present in dissolved-iron concentrations. Magnesium was the only characteristic that had a trend (increasing) in data at both stations.

INTRODUCTION

The water quality of the Nation's rivers can vary through time as a result of variations in water discharge or changes in the processes that affect water-quality characteristics. Concern about the quality of the Nation's rivers has prompted the evaluation of water-quality data for possible trends, which are gradual or abrupt changes through time. In the past, detecting trends was made difficult by the lack of consistent and comprehensive water-quality data.

In 1972, the U.S. Geological Survey established the National Stream Quality Accounting Network (NASQAN). Sample collection began at stations located near the outlets of major drainage basins (Ficke and Hawkinson, 1975, p. 5). The network has expanded since then, including stations farther upstream in the major drainage basins and in smaller coastal basins (Smith and others, 1987, p. 1). The station Flathead River at Flathead, British Columbia (station 12355000), was added to the NASQAN network in October 1974. The station Flathead River at Columbia Falls, Montana (station 12363000), was added in February 1979 (fig. 1).

Previous studies included water-quality trend analyses at these two stations, among others. For the station Flathead River at Flathead, British Columbia (herein called Flathead station), Smith and others (1982) analyzed total phosphorus concentrations and loads for water years[1] 1975-79. Smith and Alexander (1983, 1985) reported the results of trend analyses of the concentrations of common constituents, nutrients, biological variables, and trace elements for water years 1975-81. Smith and others (1987) analyzed as many as 24 water-quality characteristics for trends for water years 1975-81. For the station Flathead River at Columbia Falls, Montana (herein called Columbia Falls station), Wells and Schertz (1983) used linear regression to analyze for trends in dissolved-solids concentrations of samples collected from March 1979 through September 1981. Although four of the five previous studies analyzed trends in data collected through water year 1981, the limited periods of record at the two stations did not permit analysis for trends in similar characteristics for a substantial concurrent period.

The purpose of this report, which was prepared in cooperation with the Montana Department of Natural Resources and Conservation, is to describe the methods of analysis and the trends detected in data for selected water-quality characteristics at the Flathead station for water years 1975-86 and at the Columbia Falls station for water years 1979-86. The water-quality characteristics analyzed were: pH, alkalinity, dissolved solids, common constituents, nutrients, iron, organic carbon, and suspended sediment. The results at the two stations are compared for those water-quality characteristics displaying significant trends.

Trend analyses were performed using nonparametric statistical methods on water-quality data collected during water years 1975-86 at the Flathead station and water years 1979-86 at the Columbia Falls station. Trends at the two sites are compared for the concurrent period, water years 1979-86. However, the period of record for some water-quality characteristics was shorter because of changes in laboratory methods, termination of laboratory analyses for some characteristics, and commencement of analyses for other characteristics. Some characteristics were adjusted prior to testing for trends to remove the effects of variation in water discharge. Other characteristics were not adjusted because of lack of a significant relation with water discharge or because the percentage of data reported as being less than the detection limit of the analysis made the adjusting equations unreliable.

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[1] A water year is the 12-month period October 1 through September 30. It is designated by the calendar year in which it ends.

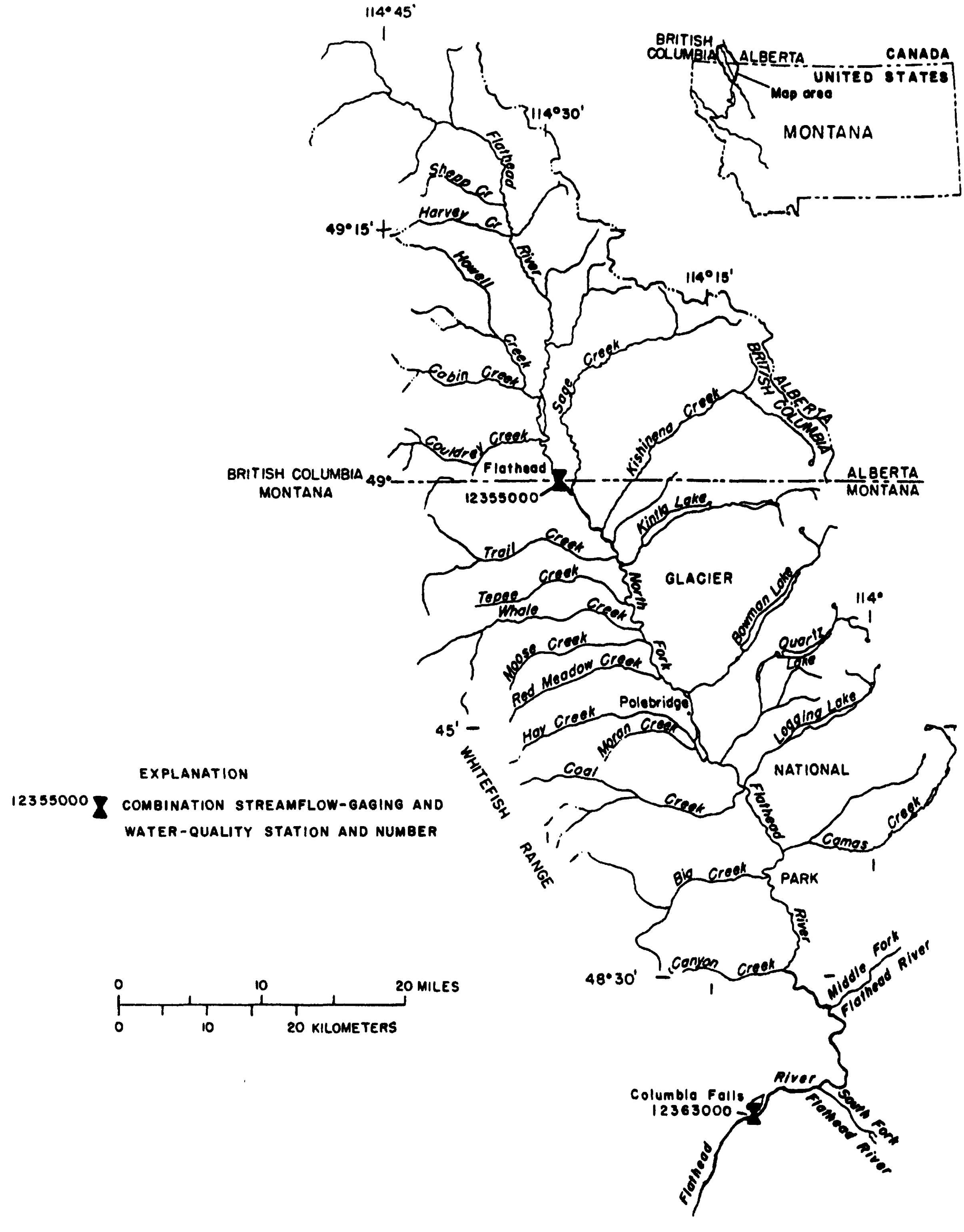

Figure 1.--Location of the Flathead River and sampling stations used in the trend analyses. The Flathead River of British Columbia becomes the North Fork Flathead River in Montana. The North Fork Flathead River joins with the Middle Fork Flathead River to form the Flathead River in Montana. Modified from Knapton (1978).

METHODS OF ANALYSIS

Review of Data

The data were reviewed prior to statistical analysis. The suitability of the data for analysis depends on sampling frequency, seasonality, sample size, changes in laboratory procedures, and the percentage of data that was reported as being less than the detection limits.

The sampling frequency varied at the stations. At the Flathead station, samples for laboratory analyses of common constituents and nutrients were collected about once monthly in water years 1975-81, bimonthly in water year 1982, and quarterly thereafter. At the Columbia Falls station, samples were collected sporadically in water years 1979 (8 samples) and 1980 (13 samples), bimonthly in water years 1981-82, and quarterly thereafter. Samples for trace elements were collected about quarterly at both sites.

Water-quality characteristics commonly display seasonality. The test statistic used in this study was calculated from data pairs within seasons to remove the effect of seasonality (Hirsch and others, 1982, p. 109; Smith and others, 1982, p. 6). The number of seasons depends on the sampling frequency; for example, 12 seasons would be specified for samples collected at monthly intervals, whereas 4 seasons would be used for samples collected quarterly (Hirsch and others, 1982, p. 109; Crawford and others, 1983, p. 57; Smith and Alexander, 1983, p. 9). Because samples for common constituents and nutrients were collected about monthly during 7 of the 12 years of record at the Flathead station, 12 seasons were used. Samples for constituents and nutrients were collected at least bimonthly in one-half the years at the Columbia Falls station, so six seasons were used for that station. Four seasons were used in the trend tests for trace elements.

Use of trend tests requires an adequate sample size. The sample size depends on the number of valid data values in each season and on the number of years that data have been collected. Smith and others (1982, p. 3) used stations that had at least 24 values. Smith and Alexander (1983, p. 9) required at least 24 values for characteristics sampled monthly and bimonthly and 16 values for characteristics sampled quarterly. A minimum sample size of 30 was used in this study. Analyses were not reported for all characteristics throughout the period studied. Laboratory alkalinity was not determined prior to water year 1980. Analyses for total recoverable metals were not reported after water year 1980, and analyses for some nitrogen species and organic carbon were not reported after water year 1981. These characteristics were retained for trend analyses if the number of reported values was equal to or greater than 30.

Some of the analytical procedures used by the laboratory changed during the period studied. For example, the procedure for analyzing phosphorus changed in the spring of 1978. Therefore, data on phosphorus concentrations reported prior to May 1978 were excluded from the trend analysis.

Some of the constituent concentrations commonly were reported as being less than the detection limits. Such data pose no theoretical or computational problem in the trend test because relative ranks of the data are being compared (Hirsch and others, 1982, p. 111; Smith and Alexander, 1983, p. 12; Smith and others, 1987, p. 2). Characteristics were included in this study if less than 45 percent of the data was reported as being less than the detection limit.

The hydrologic characteristics used in the trend tests and the period of data availability are listed in table 1 for the Flathead station and in table 2 for the Columbia Falls station. Characteristics with data reported as being less than the detection limit are indicated by "yes," whereas characteristics with all data reported as being larger than the detection limits are indicated by "no." The percentage of data reported as being less than the detection limit is also given.

Table 1.--*Hydrologic characteristics used in the trend analyses of data from the Flathead River at Flathead, British Columbia*

[Units of measurement are milligrams per liter except as follows: discharge (cubic feet per second), pH (standard units), and iron (micrograms per liter). Abbreviation: °C, degrees Celsius. --, no data]

Characteristic	Period of data availability (water year)	Values less than detection limit	
		Reported	Percent of all values
Discharge, water, instantaneous	1975-86	--	--
pH	1975-86	No	--
Alkalinity, laboratory, total as $CaCO_3$	1980-86	No	--
Solids, dissolved, residue at 180 °C	1975-86	No	--
Calcium, dissolved as Ca	1975-86	No	--
Magnesium, dissolved as Mg	1975-86	No	--
Sodium, dissolved as Na	1975-86	No	--
Sulfate, dissolved as SO_4	1975-86	No	--
Chloride, dissolved as Cl	1975-86	No	--
Nitrogen, NO_2+NO_3 total as N	1975-81	Yes	8
Nitrogen, NO_2+NO_3 dissolved as N	1979-86	Yes	43
Nitrogen, ammonia, total as N	1977-81,86	Yes	16
Nitrogen, ammonia, dissolved as N	1977-86	Yes	6
Nitrogen, organic, total as N	1977-81,86	No	--
Nitrogen, organic, dissolved as N	1978-81	No	--
Phosphorus, total as P	1977-86	Yes	13
Phosphorus, dissolved as P	1977-86	Yes	19
Iron, total recoverable as Fe	1975-80	No	--
Iron, dissolved as Fe	1975-86	Yes	40
Carbon, organic, total as C	1975-81	No	--
Carbon, organic, dissolved as C	1975-81	No	--
Sediment, suspended	1975-86	No	--

Streamflow Adjustment

Variation in the water discharge of streams might cause trends in some water-quality characteristics or mask trends due to other causes in other characteristics. A flow-adjusting procedure was used for characteristics displaying a significant relation to discharge (Hirsch and others, 1982, p. 120; Smith and others, 1982,

Table 2.--*Hydrologic characteristics used in the trend analyses of data from the Flathead River at Columbia Falls, Montana*

[Units of measurement are milligrams per liter except as follows: discharge (cubic feet per second), pH (standard units), and iron (micrograms per liter). Abbreviation: °C, degrees Celsius. --, no data]

Characteristic	Period of data availability (water year)	Values less than detection limit	
		Reported	Percent of all values
Discharge, water, instantaneous	1979-86	--	--
pH	1979-86	No	--
Alkalinity, laboratory, total as $CaCO_3$	1980-86	No	--
Solids, dissolved, residue at 180 °C	1979-86	No	--
Calcium, dissolved as Ca	1979-86	No	--
Magnesium, dissolved as Mg	1979-86	No	--
Sodium, dissolved as Na	1979-86	No	--
Potassium, dissolved as K	1979-86	No	--
Sulfate, dissolved as SO_4	1979-86	Yes	8
Chloride, dissolved as Cl	1979-86	No	--
Nitrogen, NO_2+NO_3, dissolved as N	1980-86	Yes	44
Nitrogen, ammonia, dissolved as N	1980-86	Yes	5
Phosphorus, dissolved as P	1978-86	Yes	33
Iron, dissolved as Fe	1979-86	Yes	30
Sediment, suspended	1979-86	No	--

p. 6-7; Smith and Alexander, 1983, p. 9-10). The adjustment is intended to remove the effects of variation in discharge. Equations describing the relation between discharge and the water-quality characteristics were fitted by regression. The equation explaining the largest percentage of the variance in the water-quality data was selected and used to estimate values. These estimated values were subtracted from the reported values to produce the "adjusted" data. The adjusted data were tested for trends.

Adjustment of some characteristics might not be appropriate. If the relation between discharge and a characteristic is not significant according to the regression analysis, the adjustment is not appropriate (Smith and others, 1982, p. 8; Crawford and others, 1983, p. 12). Numerous data reported as being less than the detection limit may make adjustment unreliable (Crawford and others, 1983, p. 11; (Smith and others, 1987, p. 2). Characteristics that had no more than 13 percent of the data reported as being less than the detection limit were evaluated for possible flow adjustment. The data reported as being less than the detection limit were set equal to one-half the detection limit, and a regression of the characteristic as a function of discharge was computed. Next, the data reported as being less than the detection limit were deleted, and the regression was recomputed. If the coefficients changed appreciably, or if the relation was not significant, the characteristic was not flow adjusted.

Trend Tests

The seasonal Kendall test, which is a nonparametric statistical method, was used to test for gradual trends. The test was developed for water-quality time series displaying seasonality. This test is described fully by Hirsch and others (1982), Smith and others (1982), and Smith and Alexander (1983).

A significance level of 0.10 was selected. At this level, there is a 10-percent probability that the seasonal Kendall test will indicate a trend when no trend exists.

An estimate of the magnitude of change per year caused by a trend can be obtained by using the slope estimate. Hirsch and others (1982, p. 117) and Smith and others (1982, p. 6) defined the slope estimate to be the median of the slopes of all the data pairs compared in the seasonal Kendall test. The slope estimates were determined in this study for all characteristics displaying trends except those with numerous data reported as less than the detection limit, which makes the slope estimate unreliable (Smith and others, 1987, p. 2). Slope estimates were not determined if more than 13 percent of the data was reported as being less than the detection limit.

The slope estimate can be expressed as a percentage change per year to make comparisons between characteristics easier. Smith and others (1982, p. 13, 20) converted the slope estimate of the characteristic to a percentage by dividing the estimate by the mean of the characteristic, then multiplying by 100. When the natural logarithm of the characteristic is analyzed for trend, the slope estimate (b) is converted to a percentage as follows: $100 \cdot (\exp(b)-1)$ (Crawford and others, 1983, p. 12-13). In this study, all slope estimates were converted to percentages using these procedures.

The trend test is an exploratory statistical technique. The slopes are estimates of the change in value per year during the period analyzed. No inferences can be made regarding the continuation of a trend into the future. Also, a trend in a characteristic might be statistically significant but have little physical, biological, or chemical significance.

TRENDS IN WATER-QUALITY CHARACTERISTICS

Trends in Flathead River at Flathead, British Columbia

The results of the flow-adjusting procedure and trend tests for data from the Flathead station are given in table 3. Relations between discharge and the following characteristics were statistically significant: alkalinity, dissolved solids, calcium, magnesium, sodium, sulfate, total organic nitrogen, total phosphorus, total recoverable iron, and suspended sediment. Some data for total phosphorus concentrations were reported as being less than the detection limit, but the relations with discharge were unaffected when these data were included in the regression analyses. The relations between discharge and the following characteristics were

Table 3.--*Results of the flow-adjusting procedure and seasonal Kendall tests for trends in water-quality characteristics of the Flathead River at Flathead, British Columbia*

[Units of measurement in milligrams per liter except as follows: pH (standard units) and iron (micrograms per liter). Abbreviation: °C, degrees Celsius. Data adjusted--Yes, data adjusted using discharge as the explanatory variable; No, data not adjusted. Trend results--No, trend was not detected at the 0.10 significance level; +, trend was significant and increased; -, trend was significant and decreased. --, no data]

	Flow-adjusting procedures			Trend results	
Characteristic	Characteristic related to discharge	Values less than detection limit	Data adjusted	Trend	Slope estimate (percent per year)
pH	No	No	No	No	--
Alkalinity, laboratory, total as $CaCO_3$	Yes	No	Yes	No	--
Solids, dissolved, residue at 180 °C	Yes	No	Yes	+	0.3
Calcium, dissolved as Ca	Yes	No	Yes	+	.3
Magnesium, dissolved as Mg	Yes	No	Yes	+	.4
Sodium, dissolved as Na	Yes	No	Yes	+	3.7
Sulfate, dissolved as SO_4	Yes	No	Yes	No	--
Chloride, dissolved as Cl	No	No	No	No	--
Nitrogen, NO_2+NO_3, total as N	Unknown	Yes	No	-	--
Nitrogen, NO_2+NO_3, dissolved as N	Unknown	Yes	No	+	--
Nitrogen, ammonia, total as N	Unknown	Yes	No	+	--
Nitrogen, ammonia, dissolved as N	Unknown	Yes	No	+	--
Nitrogen, organic, total as N	Yes	No	Yes	+	7.5
Nitrogen, organic, dissolved as N	No	No	No	No	--
Phosphorus, total as P	Yes	Yes	Yes	+	2.6
Phosphorus, dissolved as P	Unknown	Yes	No	No	--
Iron, total recoverable as Fe	Yes	No	Yes	No	--
Iron, dissolved as Fe	Unknown	Yes	No	-	--
Carbon, organic, total as C	No	No	No	No	--
Carbon, organic, dissolved as C	No	No	No	No	--
Sediment, suspended	Yes	No	Yes	No	--

not statistically significant: pH, chloride, dissolved organic nitrogen, and organic carbon (total and dissolved). Other characteristics had more than 13 percent of the data reported as being less than the detection limit or the adjusting relations were appreciably affected by the data reported as being less than the detection limit; flow adjustment for these characteristics was considered to be unreliable ("unknown" in table 3). These characteristics were nitrite plus nitrate nitrogen (total and dissolved), ammonia nitrogen (total and dissolved), dissolved phosphorus, and dissolved iron.

The seasonal Kendall test was applied to the adjusted data of the characteristics related to discharge and to the unadjusted data of the remaining characteristics. The following characteristics had statistically significant increasing trends in adjusted data (table 3): dissolved solids, calcium, magnesium, sodium, total organic nitrogen, and total phosphorus. The following characteristics had statistically significant increasing trends in unadjusted data: dissolved nitrite plus nitrate nitrogen and ammonia nitrogen (total and dissolved). Decreasing trends existed in the unadjusted data for total nitrite plus nitrate nitrogen and for dissolved iron. No trends were detected in pH, alkalinity, sulfate, chloride, dissolved organic nitrogen, dissolved phosphorus, total recoverable iron, organic carbon (total and dissolved), or suspended sediment.

The periods analyzed in the trend tests were not the same for all variables (table 1). The increasing trends in dissolved solids, calcium, magnesium, and sodium were detected in data for water years 1975-86. The decreasing trend in dissolved iron also occurred during this period. The decreasing trend in total nitrite plus nitrate nitrogen was for water years 1975-81. The increasing trend for dissolved nitrite plus nitrate nitrogen was for water years 1979-86. Dissolved ammonia nitrogen had an increasing trend during water years 1977-86. Increasing trends for two nitrogen constituents--total ammonia nitrogen and total organic nitrogen--were present in data for water years 1977-81 and 1986. There was an increasing trend in total phosphorus from May 1978 through water year 1986.

The slope estimates for characteristics with significant trends, except those with numerous data (more than 13 percent) reported as being less than the detection limit, are given in table 3. Dissolved solids, calcium, and magnesium had small increases, ranging from 0.3 to 0.4 percent per year. The mean concentrations of these variables were 133, 39, and 8.2 mg/L, respectively. Sodium, which increased 3.7 percent per year, had a mean concentration of 0.8 mg/L. Total organic nitrogen, which increased 7.5 percent per year, had a mean concentration of 0.3 mg/L. The slope estimate for total phosphorus may have been affected by the data (13 percent) reported as being less than the detection limit. Total phosphorus increased 2.6 percent per year. The mean total phosphorus concentration was about 0.023 mg/L.

Trends in Flathead River at Columbia Falls, Montana

The results of the flow-adjusting procedure and trend tests for data from the Columbia Falls station for water years 1979-86 are given in table 4. Relations between discharge and the following characteristics were statistically significant: alkalinity, dissolved solids, calcium, magnesium, sodium, sulfate, and suspended sediment. Some data less than the detection limit were reported for concentrations of sulfate, but the relation between discharge and sulfate was unaffected when these data were included in the regression analyses. Additional characteristics not related to discharge were pH, potassium, and chloride. Other characteristics had more than 13 percent of the data reported as being less than the detection limit or the adjusting relations were appreciably affected by the data reported as being less than the detection limit; flow adjustment for these characteristics was considered to be unreliable ("unknown" in table 4). These characteristics were concentrations of dissolved nitrite plus nitrate nitrogen, dissolved ammonia nitrogen, dissolved phosphorus, and dissolved iron.

The seasonal Kendall test was applied to the adjusted data of the characteristics related to discharge and to the unadjusted data of the remaining characteris-

Table 4.--*Results of the flow-adjusting procedure and seasonal Kendall tests for trends in water-quality characteristics of the Flathead River at Columbia Falls, Montana*

[Units of measurement in milligrams per liter except as follows: pH (standard units) and iron (micrograms per liter). Abbreviation: °C, degrees Celsius. Data adjusted--Yes, adjusted using discharge as the explanatory variable; No, not adjusted. Trend results--No, trend was not detected at the 0.10 significance level; +, trend was significant and increased; -, trend was significant and decreased. --, no data]

	Flow-adjusting procedures			Trend results	
Characteristic	Characteristic related to discharge	Values less than detection limit	Data adjusted	Trend	Slope estimate (percent per year)
pH	No	No	No	No	--
Alkalinity, laboratory, total as $CaCO_3$	Yes	No	Yes	No	--
Solids, dissolved, residue at 180 °C	Yes	No	Yes	No	--
Calcium, dissolved as Ca	Yes	No	Yes	+	1.1
Magnesium, dissolved as Mg	Yes	No	Yes	+	.6
Sodium, dissolved as Na	Yes	No	Yes	No	--
Potassium, dissolved as P	No	No	No	No	--
Sulfate, dissolved as SO_4	Yes	Yes	Yes	-	-4.5
Chloride, dissolved as Cl	No	No	No	No	--
Nitrogen, NO_2+NO_3, dissolved as N	Unknown	Yes	No	No	--
Nitrogen, ammonia, dissolved as N	Unknown	Yes	No	No	--
Phosphorus, dissolved as P	Unknown	Yes	No	-	--
Iron, dissolved as Fe	Unknown	Yes	No	No	--
Sediment, suspended	Yes	No	Yes	No	--

tics. Significant trends were found in the adjusted data for calcium, magnesium, and sulfate and in the unadjusted data for dissolved phosphorus (table 4). Increasing trends occurred for calcium and magnesium; decreasing trends occurred for sulfate and dissolved phosphorus. No trends were detected in pH, alkalinity, dissolved solids, sodium, potassium, chloride, dissolved nitrite plus nitrate nitrogen, dissolved ammonia nitrogen, dissolved iron, or suspended sediment.

The slope estimates for the variables that had significant trends, except dissolved phosphorus, are given in table 4. Numerous data (more than 13 percent) reported as being less than the detection limit made the slope estimate for dissolved phosphorus unreliable. Calcium, which increased 1.1 percent per year, had a mean concentration of 24 mg/L. Magnesium, which increased 0.6 percent per year, had a mean concentration of 6.0 mg/L. Sulfate, which decreased 4.5 percent per year, had a mean concentration of 5.6 mg/L.

Comparison of Trends

The trend tests were repeated for some of the characteristics at the Flathead station. The characteristics that were retested were those having data reported at both stations for water years 1979-86. The following characteristics no longer displayed trends: dissolved solids, calcium, sodium, and dissolved ammonia nitrogen. Trends were still present in concentrations of magnesium, dissolved nitrite plus nitrate nitrogen, and dissolved iron. Magnesium and dissolved nitrite plus nitrate nitrogen had increasing trends; dissolved iron had a decreasing trend.

The characteristics with trends at either station are listed in table 5. The results of the trend analysis at the Columbia Falls station have been repeated in table 5 for ease of comparison. Magnesium concentration increased 0.8 percent per year at the Flathead station and 0.6 percent per year at the Columbia Falls station. Dissolved nitrite plus nitrate nitrogen increased at the Flathead station, but had no trend at the Columbia Falls station. Dissolved iron decreased at the Flathead station but had no trend at the Columbia Falls station.

Table 5.--*Comparison of trends in water-quality characteristics of the Flathead River at Flathead, British Columbia, with trends of the Flathead River at Columbia Falls, Montana, water years 1979-86*

[Units of measurement are milligrams per liter except for iron (micrograms per liter). Trend results--No, trend was not detected at the 0.10 significance level; +, trend was significant and increased; -, trend was significant and decreased. --, no data]

Characteristic	Flathead River at Flathead, British Columbia: Trend results		Flathead River at Columbia Falls, Montana: Trend results	
	Trend	Slope estimate (percent per year)	Trend	Slope estimate (percent per year)
Calcium, dissolved as Ca	No	--	+	1.1
Magnesium, dissolved as Mg	+	0.8	+	.6
Sulfate, dissolved as SO_4	No	--	-	-4.5
Nitrogen, NO_2+NO_3, dissolved as N	+	--	No	--
Phosphorus, dissolved as P	No	--	-	--
Iron, dissolved as Fe	-	--	No	--

Factors Affecting Results

Some differences in the results of the trend tests were noted between the Flathead and Columbia Falls stations. Several factors may have contributed to these differences.

Analysis of data from different time periods can affect the results. Trends may exist during one period, then cease or reverse direction during another. Conversely, a trend may commence after a period with no trend. Many of the data for characteristics tested at the Flathead station in this study were for water years 1975-86, whereas the data at the Columbia Falls station were for water years 1979-86. Most of the previous studies used data for water years 1975-79 or 1975-81.

The data for some characteristics were adjusted for the effects of discharge. Data were adjusted: (1) if the relation between discharge and the unadjusted data was significant, (2) if no more than 13 percent of the data was reported as being less than the detection limit, and (3) if the data reported as being less than the detection limit had no appreciable effect on the relation with discharge. Trends in some characteristics may be present, but can be masked by variation in discharge. Trends in other characteristics may be introduced by trends in discharge. Although statistically significant trends in discharge were not found, there is a probability (equal to the significance level) that a trend may have occurred.

Changing laboratory and onsite methods of analysis may have affected the data and thus the outcome of the trend tests. The revision of the laboratory method for phosphorus analysis in the spring of 1978 permitted detection at smaller concentrations than the previous method. Therefore, data prior to May 1978 were not used in this study. The procedure for onsite preservation of nutrient samples changed at the beginning of water year 1981, which may have affected the results for nitrogen and phosphorus.

The choice of the significance level can affect the results of the trend tests. There is a 10-percent probability that the seasonal Kendall test will indicate a trend when no trend exists. The probability of concluding that a trend does not exist when, in fact, it does increases with decreasing significance levels, although the quantity of increase is generally not known.

The results of trend tests may also be affected by the choice of the number of seasons. The number of seasons selected can affect the sample size, and in turn, the calculated probability that a trend exists. Adjusted magnesium concentrations at the Columbia Falls station were tested for trends using 12, 6, and 4 seasons. The calculated probabilities were 0.012, 0.037, and 0.094. If a significance level of 0.05 had been selected before the test, the conclusion that a trend existed would have been drawn when 12 and 6 seasons were used, but not when 4 seasons were used.

Some of the differences in data between the Flathead and the Columbia Falls stations may be caused by intervening tributary inflows as well as nonpoint source inflows to the mainstem Flathead River. Numerous tributaries join the North Fork Flathead River downstream from the Flathead station (fig. 1). The mainstem Flathead River in Montana is formed by the joining of the North and Middle Forks, and the South Fork flows into the Flathead River--all upstream from the Columbia Falls station (fig. 1). The differences between the two stations may be due to differences between the concentrations of constituents in the tributary inflows and the mainstem.

SUMMARY

Data for selected water-quality characteristics were evaluated for trends at two sampling stations--Flathead River at Flathead, British Columbia (the Flathead station), and Flathead River at Columbia Falls, Montana (the Columbia Falls station). The results at the two stations were compared.

Data were available for different periods at the two stations. Water-quality sampling began in water year 1975 at the Flathead station and in 1979 at the Columbia Falls station. For most characteristics, sampling continued through water year 1986. Data for some water-quality characteristics were not reported for the entire period. These characteristics were analyzed for trends if there were 30 or more reported values. The data for some characteristics were adjusted for the effects of discharge. Data were adjusted: (1) if the relation between discharge and the unadjusted data was significant, (2) if no more than 13 percent of the data was reported as being less than the detection limit, and (3) if the data reported as being less than the detection limit had no appreciable effect on the relation with discharge.

The seasonal Kendall test was applied to the data from the Flathead station. Increasing trends occurred in the adjusted data for dissolved solids, calcium, magnesium, sodium, total organic nitrogen, and total phosphorus. Increasing trends occurred in the unadjusted data for dissolved nitrite plus nitrate nitrogen and ammonia nitrogen (total and dissolved). Decreasing trends were present in unadjusted data for total nitrite plus nitrate nitrogen and for dissolved iron. No trends were detected in pH, alkalinity, sulfate, chloride, dissolved organic nitrogen, dissolved phosphorus, total recoverable iron, organic carbon (total and dissolved), or suspended sediment. Slope estimates were used to provide an estimate of the change per year. The increase in adjusted data, in percent per year, was 0.3 for dissolved solids, 0.3 for calcium, 0.4 for magnesium, 3.7 for sodium, 7.5 for total organic nitrogen, and 2.6 for total phosphorus. Estimates of change per year were not made for characteristics that had more than 13 percent of the data reported as being less than the detection limit, which makes the slope estimates unreliable.

The seasonal Kendall test was applied to the data from the Columbia Falls station. Increasing trends were present in the adjusted data for calcium and magnesium, and a decreasing trend was present in the adjusted data for sulfate. A decreasing trend was present in the unadjusted data for dissolved phosphorus. No trends were detected in data for pH, alkalinity, dissolved solids, sodium, potassium, chloride, dissolved nitrite plus nitrate nitrogen, dissolved ammonia nitrogen, dissolved iron, or suspended sediment. The increase in adjusted data, in percent per year, was 1.1 for calcium and 0.6 for magnesium; the decrease was 4.5 for sulfate.

The seasonal Kendall test also was applied to data from each station for a concurrent period, water years 1979-86. Trends were present in six characteristics at one or both stations. Only magnesium displayed a trend (increasing) at both stations. Magnesium increased 0.8 percent per year at the Flathead station. Sulfate and dissolved phosphorus had no trends at the Flathead station, but decreasing trends at the Columbia Falls station. Calcium had no trend at the Flathead station, but an increasing trend at the Columbia Falls station. Dissolved nitrite plus nitrate nitrogen had an increasing trend at the Flathead station and no trend at the Columbia Falls station. Dissolved iron had a decreasing trend at the Flathead station, but no trend at the Columbia Falls station.

Several factors may have contributed to the differences in trends noted in this study. Some of these factors are the different time periods included in the analyses, flow adjustment of data for some characteristics but not other characteristics, changing laboratory and onsite analytical methods, the chosen significance level, the number of seasons selected, and tributary inflows between the Flathead and the Columbia Falls stations.

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